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# Salinity Versus Putrescine and Calcium and Its Effects on Growth and Mineral Status of Jatropha Plants

**Hussein, M. M.*, Hani A. Mansour*, Sherif S. Saad*** and **Camilia, Y. El-Dewiny****

**Water Relations and Field Irrigation Dept., Agricultural and Biological Research Institute, NRC, Dokki, Cairo, Egypt*
*** Soils and Water Use Dept., Agricultural and Biological Research Institute, NRC, Dokki, Cairo, Egypt*

A pot experiment was conducted in the greenhouse of the National Research Centre in Cairo, Egypt, during the summer of 2023 to study the effects of growth regulators and calcium on the growth of Jatropha plants under saline conditions. Plants were irrigated with saline water at concentrations of 200, 2500, and 5000 ppm. After 21 and 35 days, the plants were treated with 200 ppm putrescine, a combination of 200 ppm putrescine and 200 ppm calcium nitrate, and distilled water as a control. The results showed that saline irrigation reduced plant growth and biomass compared to freshwater irrigation. The most significant effect was observed at high salinity levels (5000 ppm) compared to moderate levels (2500 ppm). Nitrogen concentration decreased as salinity increased, while potassium and magnesium levels rose at moderate salinity but declined at higher concentrations. The opposite trend was observed for phosphorus. Freshwater irrigation, combined with foliar application of 200 ppm putrescine and calcium nitrate, improved plant growth, although this effect diminished under saline conditions. Sodium concentration decreased with the use of growth regulators compared to the control. The integration of calcium and polyamines proved to be an effective approach to mitigating the negative effects of salinity on plant growth. Nutrient adjustments should be tailored to specific salt levels and environmental conditions to improve plant resistance.

**Keywords:** Calcium nitrate, Growth regulator, Jatropha (*Jatropha curcus L.*), Salinity,and Putrescine.

## Introduction

It is well known that fusel fuel consumed rapidly owing to face the increasing of population needs and expected to completely exhaust or the oil deposit well gone at 2052 (Ecotdricity, British leading green energy suppliers). In recent years alternative emerging and building a green economy have become hot topics NWF (National Wild Federation).Green energy from plants such as corn and switch grass for ethanol or soybean and jatropha for biodiesel help to decrease the consumption of traditional fuel which led to lower the worming of earth and depressing pollution, (Ecotricity, 2022).

Plants exhibited differing levels of tolerance to environmental conditions including heat, drought, cold, salt, and mineral stress (Awad and Boutros 1987; Munns 1993; Abd El Khader et al., 2012; Hussein et al., 2013; Abd El-Baky et al., 2013; Hussein et al., 2014). Marschner (1995) observed that plant species exhibit variability in their sensitivity to salt stress. A number of studies have examined the response of Jatropha plants to salt stress (Patel et al., 2010; Hussein et al., 2012 and 2012a; Al-Ashry et al., 2013; Hussein et al., 2013; Sing, 2014 .(

Polyamines are low-molecular-weight polycations found in all plants (Altman and Levin, 1993). Generated in the Kuto glutamic acid pathway of amino acid biosynthesis, which produces arginine and ornithine, regarded as the two precursors for polyamine synthesis (Altman and Levin, 1993). Putrescine, a type of polyamine, is regarded as a plant growth regulator or a second-generation messenger and is naturally present in plant tissues (Galston and Sawheny, 1990). These materials are implicated in numerous physiological processes, including membrane permeability, the retardation of senescence, chlorophyll degradation, and stress responses (Smith, 1983). Numerous writers, including Hussein et al. (2006), Gupta and Gupta

*Corresponding author email: mansourhani2011@gmail.com
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(2011), and Todrova et al. (2015), have investigated the reactions of plants to exogenous application .

Marschner (1995) showed that calcium is an essential mineral in plants, playing crucial roles in plant metabolism. Calcium regulates the absorption and distribution of other nutrients, activates various enzymes, facilitates photosynthesis, contributes to plant structure, and enhances disease resistance. Rengel (1992) and Neves et al. (2008) identified the detrimental impact of calcium on salt stress-induced damage in plants .

Various studies have documented the impact of polyamines on the alleviation of salt stress (Hussein et al., 2006; Amri et al., 2011; Abdulhussein, 2014).

**Materials and Methods:**

A pot experiment was done in the greenhouse of the National Research Centre, Dokki, Cairo, Egypt, during the summer of 2023 to investigate the effects of a growth regulator on the growth and mineral uptake of Jatropha plants cultivated under saline conditions. Plants were irrigated with 200 ppm of tap water as the control treatment, and with 2500 ppm and 5000 ppm of diluted seawater. After 21 and 35 days, the plants were treated with 200 ppm of putrescine (a polyamine) as a growth regulator, and the same dosage of the growth regulator was combined with 200 ppm of calcium nitrate. The experimental design was a split plot with eight replications.

**Table 1. Soil physical analysis.**

| PSD (%) | | | | Texture class | $\theta_S$ % on weight basis | | | HC ($cmh^{-1}$) | BD ($g/cm^3$) | P ($cm^3$ voids /$cm^3$ soil) |
|---|---|---|---|---|---|---|---|---|---|---|
| C. Sand | F. Sand | Silt | Clay | | FC | WP | AW | | | |
| 8.6 | 24.4 | 23.9 | 43.1 | Clay loam | 32.0 | 18.0 | 14.0 | 4.68 | 1.69 | 0.36 |

**Table2. Chemical characteristics of the investigated soil.**

| pH 1:2.5 | EC $dSm^{-1}$ | $CaCO_3$ % | OM % | Soluble cations meq/100g soil | | | | Soluble anions meq/100g soil | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ | $CO_3^=$ | $HCO_3^-$ | $Cl^-$ | $SO_4^=$ |
| 7.49 | 2.58 | 3.08 | 0.87 | 2.69 | 0.58 | 2.43 | 1.24 | 0.0 | 1.05 | 2.08 | 3.85 |

| Available macro-nutrients% | | | Available micro-nutrients ppm | | | |
|---|---|---|---|---|---|---|
| N | P | K | Fe | Zn | Cu | Mn |
| 1.02 | 0. 22 | 1.25 | 4.67 | 4.08 | 9.14 | 4.53 |

**Table 3. Chemical analysis of sea water used in irrigation of Jtropha plants.**

| Source | pH | EC $dSm^{-1}$ | Soluble cations (mM) | | | | Soluble anions (mM) | | | | Total soluble salts mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Na^+$ | $K^+$ | $Mg^{++}$ | $Ca^{++}$ | $CO_3^=$ | $HCO_3^-$ | $Cl^-$ | $SO_4^=$ | |
| Sea water | 7.94 | 53 | 448 | 11.3 | 48 | 26.2 | 1.7 | 3.8 | 505 | 22 | 32000 |

Seeds of Jatropha (Jatropha curcas L.) were seeded on April 8, 2014, in earthenware pots measuring 40 cm, containing 10 kg of clay loamy soil. Certain physical and chemical parameters of the soil are presented in Tables 1 and 2. Irrigation using saline water treatments commenced 30 days post-sowing. Table (3) presents the chemical analysis of the utilized seawater, while tap water (200 ppm) served as the control treatment.

Two specimens from each sub-plot were harvested, sanitized, dehydrated in an electric oven, and pulverized in a stainless steel grinder. The digestion and analysis of nutrients were conducted following the methodologies outlined by Cottenie et al. (1982).

All gathered data underwent appropriate statistical analysis as delineated by Snedecor and Cochran (1980).

**3. Result and Discussion**

The effect of salinity condition and calcium nitrat treatments on Jatropha plant growth:

The detailed commentary on the traits in the table is based on analyzing the effects of different treatments on the fresh and dry weights of the plant, distributed across various plant parts (root, stem, leaves, and the whole plant). The treatments were evaluated at three different salinity levels (200, 2500, and 5000 ppm) using the growth regulator "Putrescine" and added "Calcium Nitrate."

**First Level: 200 ppm Salinity**

Control Treatment: Fresh Weight: Results showed that the fresh weight of the root was 132 g/plant, the stem 566 g/plant, and the leaves 146 g/plant, while the total plant weight reached 845 g. Dry Weight: The dry weight of the roots was 81 g/plant, the stem 220 g, the leaves 50 g, and the total dry weight of the plant was 314 g.

**Putrescine (Putr.) Treatment:Fresh Weight**: The fresh weight increased significantly, with the root reaching 194 g, the stem 702 g, and the leaves 202 g, raising the total plant weight to 1098 g. **Dry Weight**: The root dry weight decreased to 54 g, while the stem dry weight increased to 277 g, and the leaves 48 g, resulting in a total dry weight of 379 g.

**Putrescine + Calcium Nitrate (CaNO3)Treatment: Fresh Weight**: This treatment showed significant increases in all plant parts, with the root reaching 211 g, the stem 891 g, and the leaves 175 g, bringing the total plant weight to 1277 g. **Dry Weight**: A notable increase in dry weight was observed, with the root reaching 139 g, the stem 350 g, the leaves 52 g, and the total dry weight of the plant reaching 541 g.

**Second Level: 2500 ppm Salinity**

**Control Treatment:Fresh Weight**: The fresh weight of the root decreased to 119 g, the stem to 595 g, and the leaves to 74 g, resulting in a total weight of 788 g. **Dry Weight**: The dry weight of the roots was 74 g, the stem 218 g, the leaves 128 g, and the total dry weight was 420 g.

**Putrescine (Putr.)Treatment: Fresh Weight**: This treatment showed a considerable improvement, with the root weighing 235 g, the stem 707 g, and the leaves 131 g, bringing the total weight to 1073 g. **Dry Weight**: Although the fresh weight improved, the root dry weight slightly decreased to 131 g, the stem dry weight was 212 g, and the leaves 123 g, resulting in a total dry weight of 465 g.

**Putrescine + Calcium Nitrate (CaNO3)Treatment: Fresh Weight**: This treatment produced the highest increase in fresh weight, with the root at 253 g, the stem 675 g, and the leaves 140 g, reaching a total weight of 1068 g. **Dry Weight**: The root dry weight increased to 139 g, while the stem decreased to 201 g, but the leaves significantly increased to 302 g, giving a total dry weight of 643 g.

**Third Level: 5000 ppm Salinit**

**Control Treatment: Fresh Weight**: This treatment saw a major reduction in fresh weight, with the root at 132 g, the stem 475 g, and the leaves 127 g, resulting in a total weight of 733 g. **Dry Weight**: The dry weight of the roots significantly dropped to 39 g, the stem to 119 g, and the leaves to 29 g, with a total dry weight of 267 g.

**Putrescine (Putr.)Treatment: Fresh Weight**: No significant improvement was seen, with the root at 133 g, the stem at 550 g, and the leaves at 180 g, bringing the total weight to 863 g. **Dry Weight**: The dry weight showed a slight increase in the root (63 g), the stem (149 g), and the leaves (54 g), for a total dry weight of 266 g.

Putrescine + Calcium Nitrate (CaNO3)Treatment: Fresh Weight: This treatment resulted in a small increase in fresh weight, with the root at 140 g, the stem 553 g, and the leaves 188 g, bringing the total weight to 881 g. Dry Weight: Despite the slight improvement in fresh weight, the root dry weight decreased to 53 g, while the stem increased to 290 g, but the leaves decreased to 27 g, giving a total dry weight of 317 g.

All treatments using "Putrescine" and "Putrescine with Calcium Nitrate" showed positive effects on growth compared to the control, both in fresh and dry weights, especially at lower salinity levels. As salinity increased to 5000 ppm, the improvements became less pronounced, indicating that the effectiveness of these treatments may be influenced by higher salinity levels. The addition of calcium nitrate with "Putrescine" notably enhanced the dry weight, particularly in the stem and leaves, suggesting its potential role in improving plant growth under salinity stress.

The table provides insight into the effects of salinity stress and treatments with putrescine and calcium nitrate on the growth parameters of plants, particularly fresh and dry weights of the root, stem, leaves, and whole plant. The data shows that as salinity levels increase, plant growth tends to decrease. However, treatments with growth regulators, especially putrescine combined with calcium nitrate, appear to mitigate some of the negative effects of salinity. This discussion examines the results at three salinity levels (200 ppm, 2500 ppm, and 5000 ppm) and evaluates how each treatment impacts the plant's overall growth performance.

**Effects of Salinity on Plant Growth**

At 200 ppm salinity, the control treatment demonstrated comparatively elevated fresh and dry weights in all plant components. This indicates that at low salinity, the plants undergo negligible stress, facilitating enhanced growth. Nevertheless, as the salinity concentration escalates to 2500 ppm and 5000 ppm, a notable decline in both fresh and dry weights is evident. This aligns with previous research indicating that elevated salinity levels induce osmotic stress and ion toxicity, resulting in diminished water absorption and the suppression of plant metabolic functions (Munns & Tester, 2008; Mansour et al., 2015 a-e; Mansour et al., 2019a-e; Hu et al., 2019; Abdalla et al., 2019; Jiandong et al., 2019; Abd-Elmabod et al., 2019a-b; Tayel et al., 2012a,b; Tayel et al., 2016; Hellal et al., 2019; Mansour and Pibars, 2019; Attia et al., 2019; Hellal et al., 2021; Mansour et al., 2020a-d; Mansour and Aljughaiman, 2020; Eldariry et al., 2015; EL-Hagary et al., 2015). This is evident in the reduced weights of the root, stem, and leaf under elevated salt levels.

**Effect of Putrescine on Growth**

Calcium is essential for preserving cell wall integrity and membrane stability during salt stress (White & Broadley, 2003). Calcium nitrate, in conjunction with putrescine, may yield a synergistic impact by optimizing ionic equilibrium, mitigating sodium toxicity, and augmenting the plant's resilience to saline environments. This combination was especially successful in sustaining elevated dry weights of the stem and leaves, which are essential for photosynthesis and general plant vitality.

Putrescine is a polyamine recognized for its involvement in enhancing stress tolerance in plants by stabilizing cell membranes and scavenging reactive oxygen species (Tiburcio et al., 2014). This study demonstrated that the use of putrescine alone enhanced both fresh and dry weights across all salt levels. At 200 ppm, putrescine treatment elevated the total fresh weight of the plant from 845 g (control) to 1098 g. This trend is also observed at elevated salinity levels, when putrescine augmented the total fresh weight from 788 g to 1073 g at 2500 ppm and from 733 g to 863 g at 5000 ppm. The enhancement of plant development under salt stress with putrescine treatment corroborates the idea that polyamines might augment stress tolerance and sustain growth in harsh conditions (Groppa & Benavides, 2008).

Nonetheless, the dry weight of the roots diminished with 200 ppm putrescine treatment, suggesting that although putrescine enhances overall water absorption (leading to increased fresh weight), it may not always result in greater biomass accumulation in specific plant regions. This behavior corresponds with data indicating that polyamine treatments can occasionally augment water retention, although may not substantially raise dry biomass in every instance (Ahmad et al., 2016).

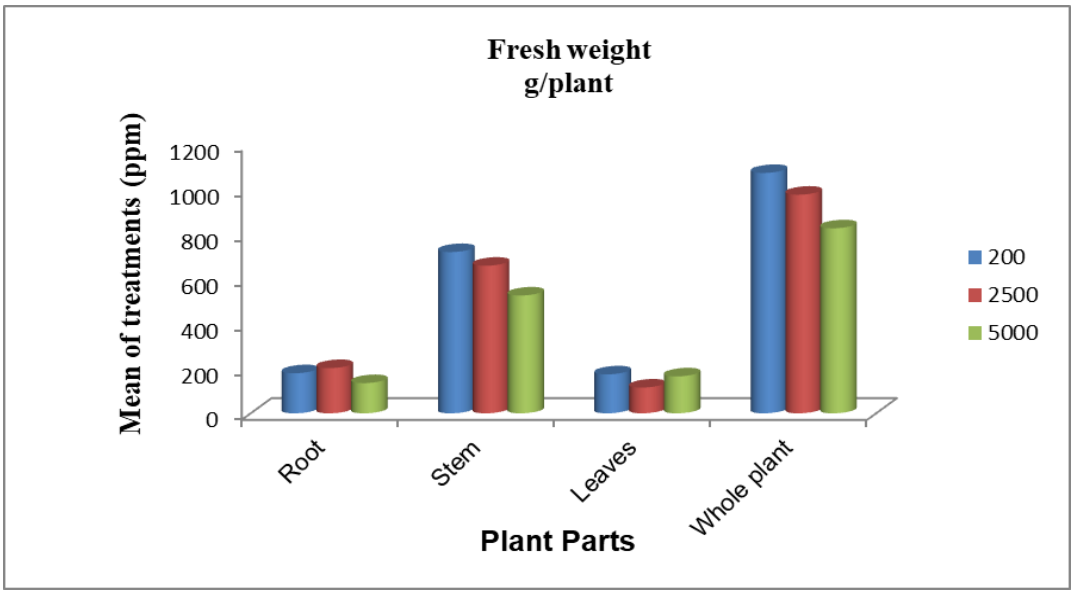
**Combined Treatment of Putrescine with Calcium Nitrate**

The amalgamation of putrescine and calcium nitrate consistently shown the most substantial enhancements across all salinity levels. At 200 ppm, the fresh weight of the plant grew to 1277 g, while the dry weight significantly rose to 541 g, in contrast to 314 g in the control group. At 2500 ppm, the fresh weight rose to 1068 g, while the dry weight attained 643 g, demonstrating that calcium nitrate amplifies the stress-relieving properties of putrescine.

At 5000 ppm, although the improvements were less pronounced compared to lower salinity levels, the combined treatment still provided a notable benefit. The total dry weight increased from 267 g in the control to 317 g under putrescine plus calcium nitrate treatment. This reinforces the idea that while salinity-induced damage is difficult to fully overcome at extremely high salinity levels, the use of stress-mitigating compounds like polyamines and calcium can still support plant survival and growth to some extent.

**Table 4: The effect of salinity degrees and calcium nitrate treatments on Jatropha plant growth:**

| Treatments in ppm | | Fresh weight g/plant | | | | Dry weight g/ plant | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Salinity** | 200 Growth regulat Putrescine +/- 200 calcium nitrate | Root | Stem | Leaves | Whole plant | Root | Stem | Leaves | Whole plant |
| **200*** | Control** | 132 | 566 | 146 | 845 | 81 | 220 | 50 | 314 |
| | Putrescine (Putr.) | 194 | 702 | 202 | 1098 | 54 | 277 | 48 | 379 |
| | Putr. + $CaNO_3$ | 211 | 891 | 175 | 1277 | 139 | 350 | 52 | 541 |
| **2500** | Control** | 119 | 595 | 74 | 788 | 74 | 218 | 128 | 420 |
| | Putrescine (Putr.) | 235 | 707 | 131 | 1073 | 131 | 212 | 123 | 465 |
| | Putr. + $CaNO_3$ | 253 | 675 | 140 | 1068 | 139 | 201 | 302 | 643 |
| **5000** | Control** | 132 | 475 | 127 | 733 | 39 | 119 | 29 | 267 |
| | Putrescine (Putr.) | 133 | 550 | 180 | 863 | 63 | 149 | 54 | 266 |
| | Putr. + $CaNO_3$ | 140 | 553 | 188 | 881 | 53 | 290 | 27 | 317 |



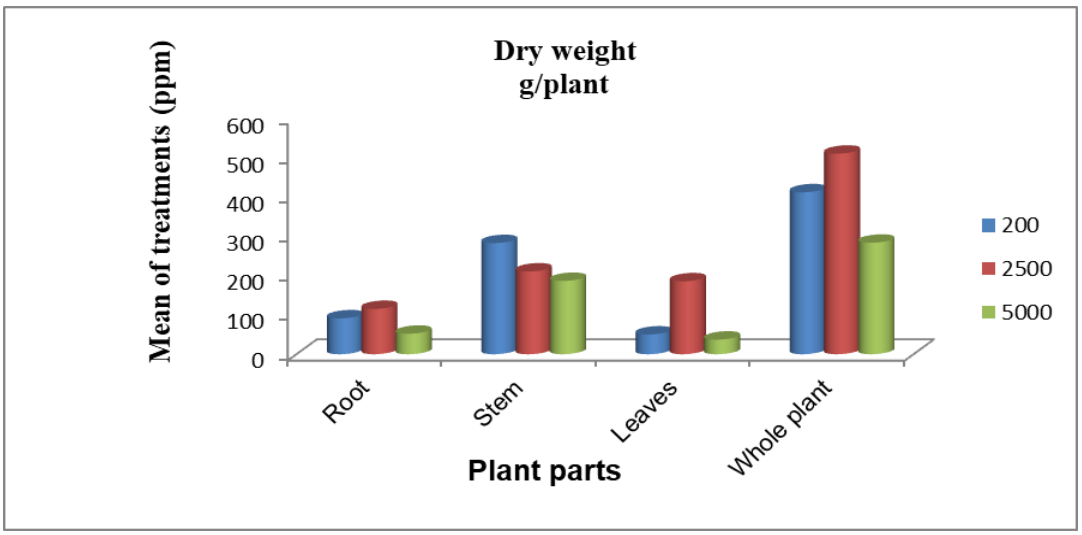




**Fig. 1. Fresh and dry weight of Jatropha plant affected by treatments grown under salinity condition.**

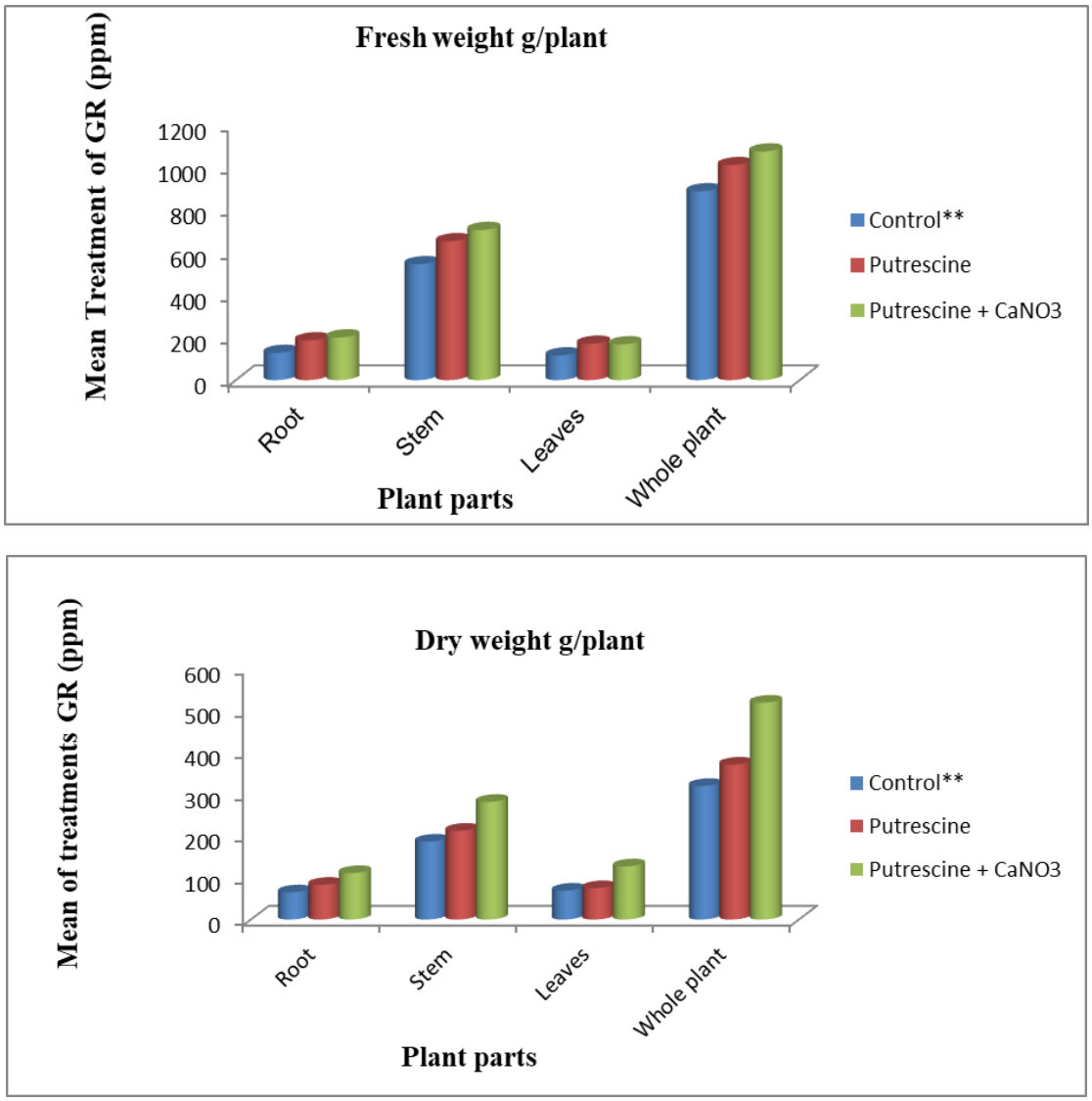



**Fig. 2. Fresh and dry weight of jatropha plant growth to spraying putrescine and calcium nitrate .**

**Table (5) Effect of spraying putrescine and calcium on jatropha plant growth.**

| 200 Growth regulat +/- 200 calcium nitrate | Fresh weight *g/ plant* | | | | Dry weight *g/ plant* | | | |
|---|---|---|---|---|---|---|---|---|
| | Root | Stem | Leaves | Whole plant | Root | Stem | Leaves | Whole plant |
| Control** | 128 | 545 | 116 | 888 | 65 | 186 | 69 | 319 |
| Putrescine | 187 | 653 | 171 | 1011 | 83 | 212 | 75 | 370 |
| Putrescine + $CaNO_3$ | 201 | 706 | 168 | 1075 | 111 | 281 | 127 | 518 |

There were consistent reductions in the fresh and dried weights of the entire stem plant. Plant height was unaffected by moderate salinity but diminished significantly under high salinity conditions. Conversely, both fresh and dry root weights rose with moderate salinity treatment but fell below control levels under high salinity in irrigation water. The dry weight of leaves exhibited a reaction identical to that of dry weight. The fresh weight of leaves per plant diminished under both salinity treatments, with a greater reduction observed in the moderate salinity condition compared to the high salt stress treatment (Table 4). Hishada et al. (2013) observed that the dry weight of both species diminished with escalating concentrations of salt; yet, both species are capable of thriving at salinities of approximately 100 mM sodium chloride (NaCl). The decrease in stomatal conductance was a

primary factor contributing to the diminished development of Jatropha spp. Gao et al. (2008) demonstrated that the fresh weights of cotyledons and radicles diminished progressively with rising NaCl concentrations, while the fresh weight of hypocotyls reached its nadir at a NaCl concentration of 150 m mol before subsequently increasing. They attributed this effect to the disruption of enzyme activity induced by salt. Niu et al. (2012) demonstrated that the total dry weight (DW) of Jatropha plants decreased by 30%, 30%, and 50%, respectively, when irrigated with saline solutions at electrical conductivities of 3.0, 6.0, and 9.0 dS m−1 in comparison to the control group. This suggests that the phenomenon may result from the impact of salt stress on oxidative defense mechanisms. Nery et al. (2009) reported that at 163 DAS (Days after sowing), Jatropha irrigated with an EC of 3.0 dS m-1 exhibited reductions in plant height, stem diameter, number of leaves, and leaf area by 9.07%, 17.63%, 23.41%, and 42.58%, respectively.

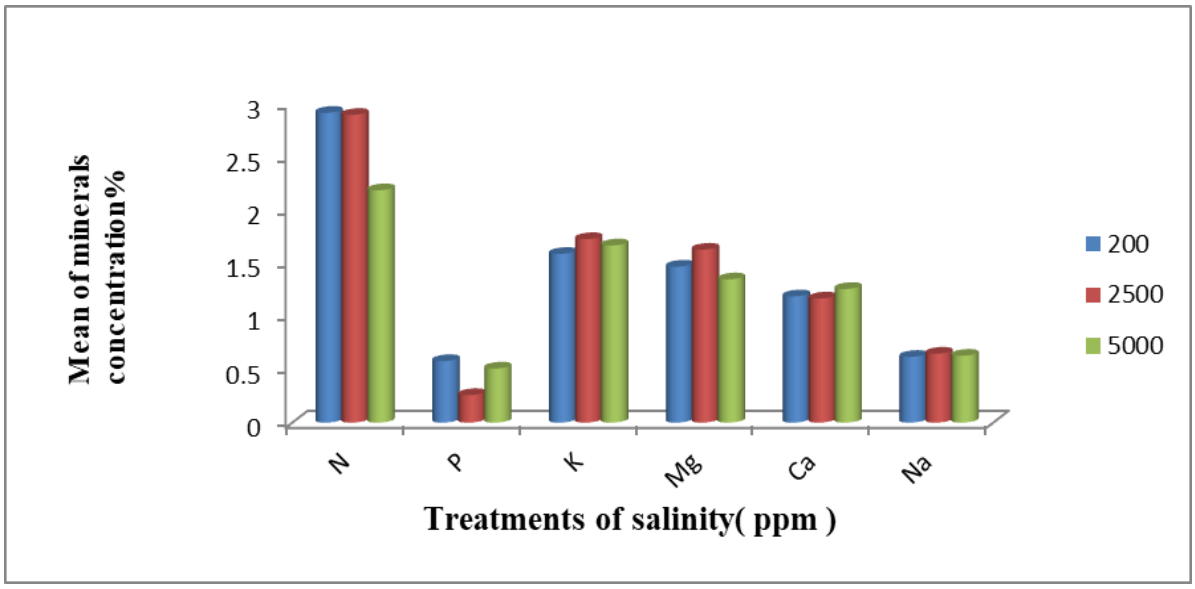



**Fig. 3. Mean macronutrients and sodium concentrations as affected by putrescine plus calcium nitrate under salinity condition.**

**Table 6. Effect of putrescine plus calcium nitrate under salinity condition on some macronutrients and sodium concentrations.**

| Treatments in ppm | | Macronutrients and sodium concentrations % | | | | | |
|---|---|---|---|---|---|---|---|
| Salinity (ppm) | 200 Growth regulat +/- 200 calcium nitrate | N | P | K | Mg | Ca | Na |
| 200 | Control** | 2.42 | 0.53 | 1.67 | 1.39 | 1.16 | 0.60 |
| | Putrescine | 3.00 | 0.52 | 1.63 | 1.58 | 1.21 | 0.63 |
| | Putrescine + $CaNO_3$ | 3.34 | 0.68 | 1.47 | 1.44 | 1.19 | 0.64 |
| Mean | | 2.92 | 0.58 | 1.59 | 1.47 | 1.19 | 0.62 |
| 2500 | Control** | 2.76 | 0,17 | 1.68 | 1.56 | 1.12 | 0.64 |
| | Putrescine | 2.85 | 0.36 | 1.64 | 1.64 | 1.19 | 9.63 |
| | Putrescine + $CaNO_3$ | 3.10 | 0.24 | 1.87 | 1.68 | 1.21 | 0.68 |
| Mean | | 2.90 | 0.26 | 1.73 | 1.63 | 1.17 | 0.65 |
| 5000 | Control** | 1.47 | 0.38 | 1.53 | 1.11 | 1.32 | 0.77 |
| | Putrescine | 2.49 | 0.56 | 1.83 | 1.46 | 1.26 | 0.64 |
| | Putrescine + $CaNO_3$ | 2.60 | 0.59 | 1.65 | 1.49 | 1.19 | 0.47 |
| Mean | | 2.19 | 0.51 | 1.67 | 1.35 | 1.26 | 0.63 |

***Mineral status***

The data shown in Tables 5 and 6 demonstrate that nitrogen concentration diminished as the irrigation water's salt concentration escalated, whereas potassium and magnesium concentrations increased with moderate salinity but tended to decline with elevated salinity levels. The opposite was true for the concentration of phosphorus. Simultaneously, calcium concentration exhibited a minor reduction with 2500 ppm salts and an increase with 5000 ppm salts, surpassing the control level. The concentration of Na seems to have no influence on salinity in this experiment. The concentration of nutrients, their uptake, and the impacts of salinity have been extensively examined by several researchers: Grattan and Grieve (1992); Ramoliya et al. (2004); Patel et al. (2010); Hussein et al. (2008); Shabaan et al. (2008); and Hussein et al. (2015). Redregous et al. (2013) investigated the impact of salinity (50.0 mM NaCl) on jatropha plants, demonstrating that NaCl inhibited photosynthesis and elevated the Na/K ratio. Niu et al. (2012) cultivated jatropha plants in solutions with electrical conductivities ranging from 3.0 to 9.0 dS/m and concluded that ion imbalance, reduced ion absorption, and specific ion toxicity impeded the total dry weight of the plants. Metwalli et al. (2015) observed that potassium, iron, zinc, and sodium levels in fig plant tissues increased gradually with rising sodium chloride concentrations. Howladar and Rady (2012) stated that salt stress diminishes water use efficiency (WUE) more significantly than it impedes calcium, potassium, and nitrate uptake by plant roots. Amri et al. (2011) examined the amounts of Na, K, and Cl in the root, apical, and basal leaves of two genotypes at harvest, 120 days post-treatment.

**Table 7: Some macronutrients and sodium concentrations as affected by putrescine plus calcium nitrate**. **under salinity condition**

| Salinity | 200 Growth regulat +/- 200 calcium nitrate | Macronutrients and sodium concentrations % | | | | | |
|---|---|---|---|---|---|---|---|
| | | N | P | K | Mg | Ca | Na |
| 200 | Control** | 2.92 | 0.58 | 1.59 | 1.47 | 1.19 | 0.62 |
| 2500 | Putrescine | 2.90 | 0.26 | 1.73 | 1.63 | 1.17 | 0.65 |
| 5000 | Putrescine + $CaNO_3$ | 2.19 | 0.51 | 1.67 | 1.35 | 1.26 | 0.63 |

**Putrescine and Calcium**

Tables 7 and 8, along with Figures 1 and 2, illustrate that polyamines (PAs), specifically putrescine, spermidine, and spermine, are a category of phytohormone-like aliphatic amine natural chemicals characterized by an aliphatic nitrogen structure, found in nearly all living creatures, including plants. Evidence indicates that polyamines have a role in various physiological processes, including cell proliferation and development (Gill and Tuteia, 2010). Polyamines (PAs) are small, ubiquitous polycations that play a significant role in various aspects of plant growth and development. They are recognized for their anti-senescence and anti-stress effects, attributed to their acid-neutralizing and antioxidant properties, along with their capacity to stabilize membranes and cell walls (Zhio and Young, 2008). Put may enhance the consumption of light energy by stimulating photophosphorylation. Ioannidis and Kotzabasis (2007) recently indicated that Put is a more effective stimulator of ATP production than Spd and Spm regarding maximal percentage stimulation; yet, Spd and Spm are proficient stimulators of non-photochemical quenching. High quantities of Spd and Spm are effective uncouplers of photophosphorylation. Lolaeil et al. (2012). It was discovered that shoot length increased in olive plants treated with calcium (5-50 mg). Their data likewise demonstrate a quadratic response, indicating a decline in shoot growth at elevated CaCl2 concentrations. Mejgar et al. (2006) shown that the presence of Ca2+ in irrigation water likely enhances the preservation of the cell wall and plasma membrane while regulating ionic absorption selectivity (Melgar et al., 2005; Tattini, 2008). Furthermore, Rubio et al. (2009) highlighted that elevated Ca2+ concentrations in the plant medium enhanced both the number of fruits per plant and the overall fruit output, attributable to the rise in fruit weight.

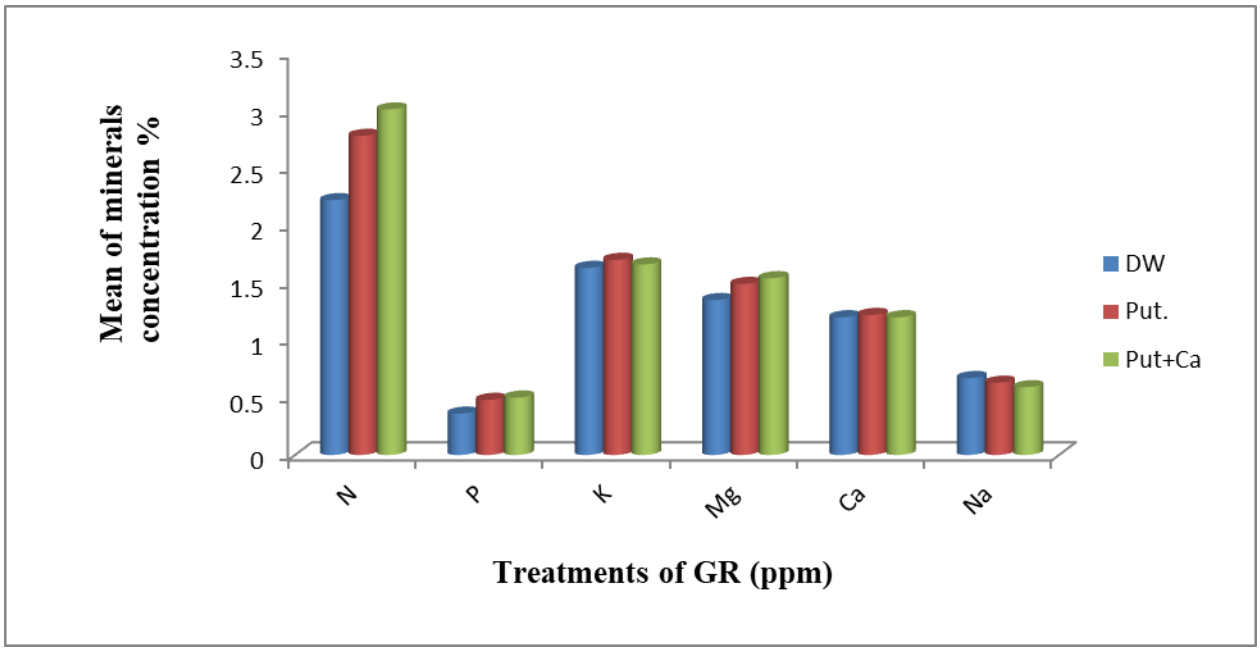



**Fig. 4. Mean Macronutrients concentration as affected by putrescine and calcium.**

According to the results presented in Table 7 and Figures 4 and 5, the concentrations of N, P, and Mg rose with the application of higher levels of growth regulators, although the concentration of Ca was only marginally changed. Nonetheless, sodium concentration diminished as the concentration of the growth regulator increased in comparison to the control treatment. Suleiman (2008) observed that putrescine reduced the concentrations of Na and Cl while augmenting K levels in faba bean plants. Among the three proposed methods of action, the significance of polyamines in cellular homeostasis is particularly pertinent to the mineral nutrition of plants (Smith 1983). Alam (1999) stated that calcium is significant not only for its function in ionic connections but also for its influence on physical soil conditions. The delayed application of calcium reduced the N/Ca and Ca/K ratios while elevating the calcium concentration in apple fruits (Domagala-SwaitKiewicz and PlaszczyK, 2009). Banuls et al. (1991) discovered that organ chloride analysis indicated a reduction in Cl buildup in the leaves of plants grafted onto both rootstocks with an increase in external Ca concentration, while Cl content in the roots either stayed constant or rose. The distribution data of Cl in plants indicated that elevated external Ca levels enhanced Cl accumulation in the basal stem and roots while diminishing Cl transit from roots to leaves. Hoiitnooghi et al. (2014) demonstrated that calcium treatment elevated calcium concentrations in both shoots and roots, as well as potassium concentration in roots, whereas it reduced potassium concentration in shoots and magnesium concentrations in both shoots and roots. Lolaeil et al. (2012) demonstrated that leaf Ca2+ concentration increased with elevated Ca2+ levels in saline solutions, and this increase appeared to correlate with a significant reduction in leaf Na+ concentration, which may also be modulated by leaf Ca2+ concentration. CaCl2 influenced the concentrations of leaf Na+, Ca2+, and K+ in olive plants irrigated with NaCl. Leaves were collected and examined 84 days post-initiation of the treatments. The content of leaf Na+ significantly diminished as CaCl2 increased from 0 to 90 mg L-1. The reduction in leaf potassium was 0.96, relative to the control value of 1.16 at the highest salinity conditions. A primary reaction of plants to salinity is the reduction of Ca2+ and K+ concentrations in leaves (Gorham, 1993). Rush and Epstein (1978) found a decrease in K+ concentration and K+/Na+ ratio under saline circumstances. The reduction of nitrogen is associated with an increased absorption of sodium chloride (Parida et al., 2004).

**Salinity x Putrescine and Calcium**

Sigmaz et al. (2015) investigate the effect of putrescine on long terminal repeat activation generated by salt stress in Triticum aestivum L., revealing that varying salinity levels (0-300 mM NaCl) significantly influenced this parameter, which was substantially reduced through the application of putrescine (0.3-1.0 mM). They stated that varying amounts of putrescine influence retrotransposon polymorphisms in conjunction with salt stress in plants. This is the inaugural report on this subject. The results revealed that putrescine enhances resistance to salt-induced retrotransposon polymorphisms. Capell et al. (2004) demonstrated that polyamine treatment enhanced plant tolerance to external environmental conditions. Miyamoto et al. (1993) established that polyamine therapy mitigated the detrimental effects of salt stress in many plants. Pyrimidine was also reported to safeguard DNA from enzymatic destruction. D'Agostino et al. (2005) posited that polyamines possess the ability to stimulate DNA and RNA production while safeguarding DNA replication from oxidative damage induced by salt stress. Furthermore, Abdulhussein et al. (2014) demonstrated that the detrimental impacts of high salinity irrigation water on endogenous plant hormones can be partially mitigated with the exogenous administration of Put at concentrations of 150 mg/L or 300 mg/L.

**Table 8: Response of some macronutrientsand sodium to spraying ofJoutrofa by putrescine and calcium under salinity conditions.**

| Sal ppm | GR | Macronutrients % | | | | | |
|---|---|---|---|---|---|---|---|
| | | N | P | K | Mg | Ca | Na |
| Tap W | Dw | 2.42 | 0.53 | 1.67 | 1.39 | 1.16 | 0.60 |
| | Putrascine | 3.00 | 0.52 | 1.63 | 1.58 | 1.21 | 0.63 |
| | Put+Ca | 3.34 | 0.68 | 1.47 | 1.44 | 1.19 | 0.64 |
| S1 | Dw | 2.76 | 0,17 | 1.68 | 1.56 | 1.12 | 0.64 |
| | Putrascine | 2.85 | 0.36 | 1.64 | 1.64 | 1.19 | 9.63 |
| | Put+Ca | 3.10 | 0.24 | 1.87 | 1.68 | 1.21 | 0.68 |
| S2 | Dw | 1.47 | 0.38 | 1.53 | 1.11 | 1.32 | 0.77 |
| | Putrascine | 2.49 | 0.56 | 1.83 | 1.46 | 1.26 | 0.64 |
| | Put+Ca | 2.60 | 0.59 | 1.65 | 1.49 | 1.19 | 0.47 |

The data from Neves et al. (2008) on Tetraaonia tetragonioides, treated with calcium and exposed to salinity, indicate that plants with elevated calcium levels exhibited longer stems compared to those with lower calcium levels, accumulated greater quantities of calcium under high salinity conditions, and displayed comparable leaf dry matter. Wright et al. (1992) indicated that the growth enhancement was chiefly attributable to the increase in both the quantity and surface area of leaves. Low concentrations of Ca were more efficacious in mitigating the impact of 100 mM Na+ from sodium sulfate compared to high concentrations of Ca++, likely due to the metabolic damage caused by the latter. Banuls et al. (1991) indicated that supplementary calcium alleviated the detrimental effects of salinity on plant development, defoliation, or leaf damage. Supplemental calcium was observed to alleviate the detrimental effects of salinity on plant development, defoliation, or leaf damage.

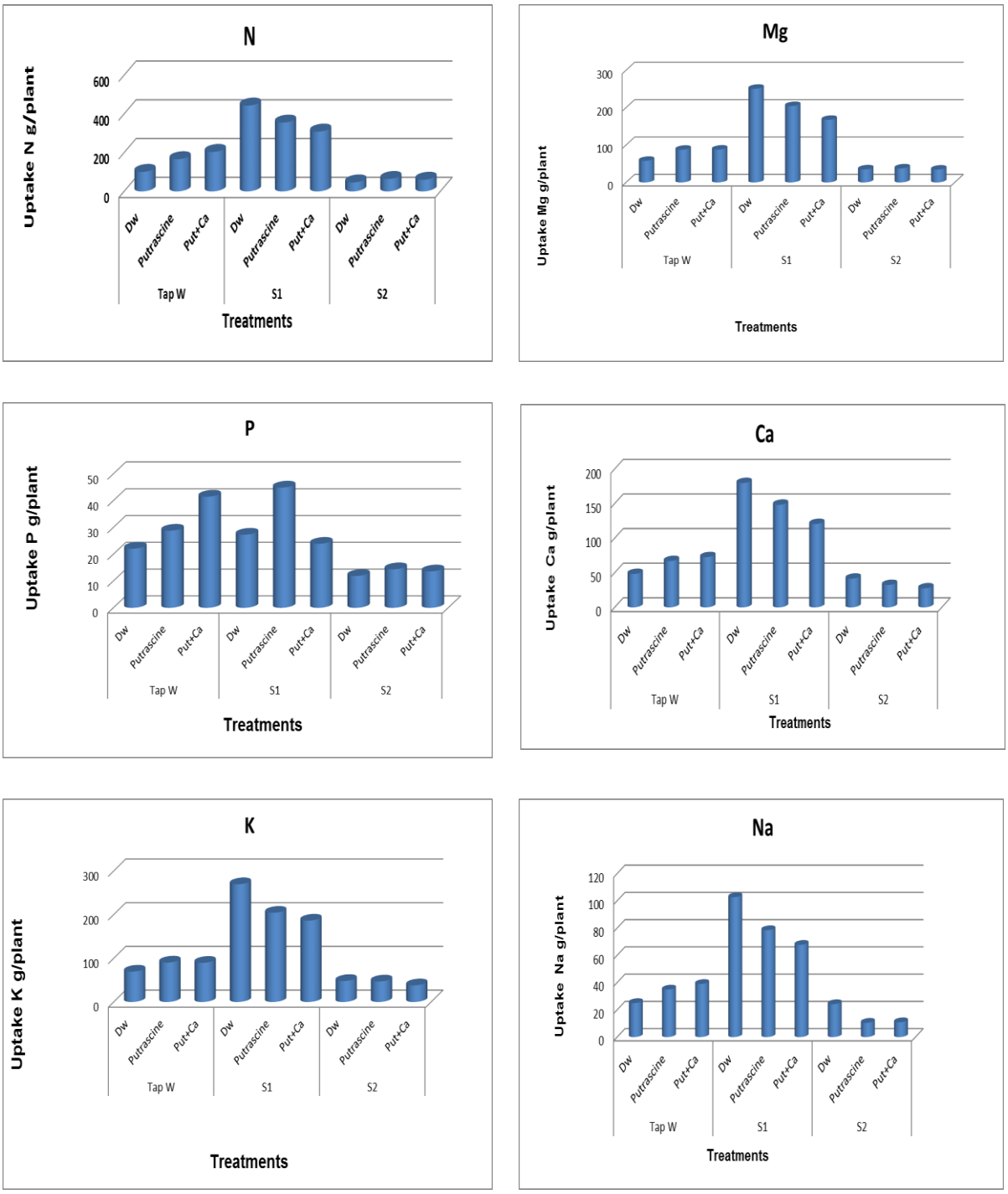



**Fig. 5. Uptake of some macronutrients and sodium by Joutrofa as a result of spraying these plant by putrescine and calcium under salinity conditions.**

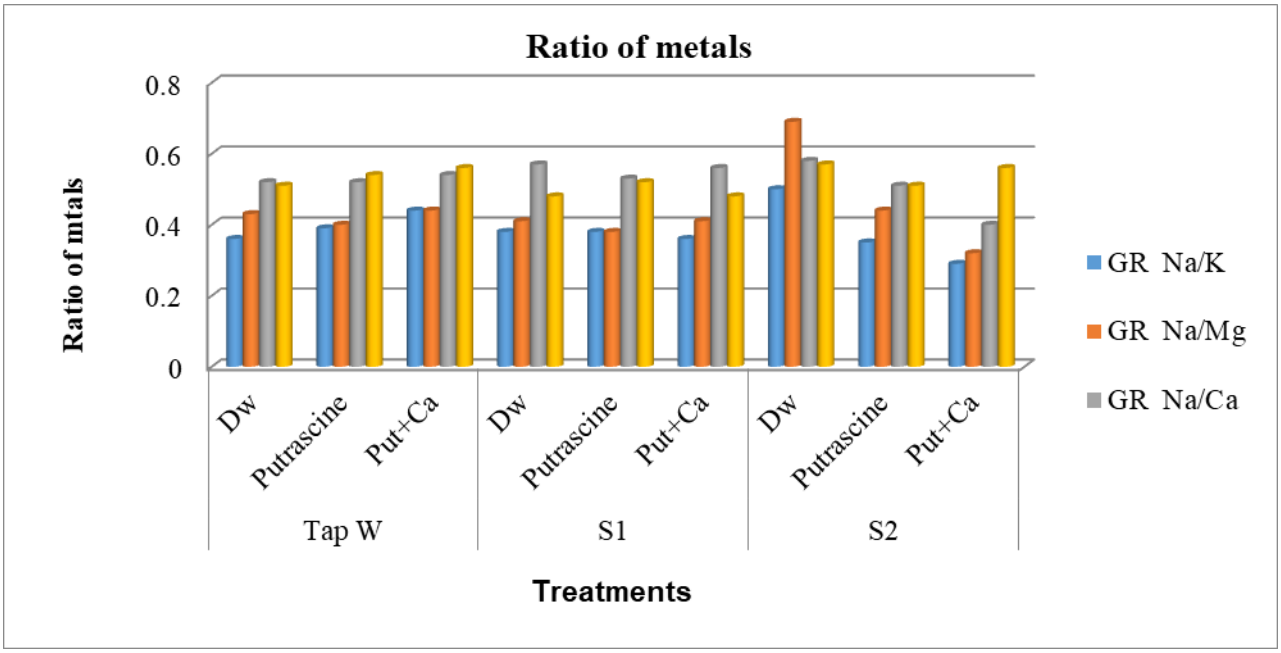



**Fig. 6. Ratio of minerals as affected by rate different of treatments salinity and amino acid.**

**Mineral status:**

Table 8 and Figures 5 and 6 illustrate that salt stress leads to an increased buildup of Na and Cl ions while diminishing the absorption of other minerals. Conversely, BA augmented the accumulation of the alternative. B Calcium, being a significant macronutrient following the primary three macronutrients, has a role in mechanisms that confer tolerance to salt stress. Calcium has several roles in metabolic activities inside plant tissues, including the regulation of cell membrane permeability, cell wall expansion and stabilization, cation and anion balance, and osmoregulation (Marschner, 1995). The detrimental impact of salinity on survival is mediated by many plant processes, as seen in Fig. 2 (Tavakkoli et al., 2010). Amri et al. (2011) demonstrated that polyamines resulted in a reduction in growth rate at salinity levels over 70 mM. As salinity levels rose, the tissue concentrations of Na and Cl increased, whereas the K/Na ratio diminished. No substantial variations were detected between the two genotypes for the amounts of Na, Cl, and K in the roots, apical leaves, and basal leaves. This outcome demonstrated that varying levels of exogenous polyamine can mitigate the impact of stress on the growth of pomegranate. Bassett-Philip (1980) noted that elevated calcium levels diminished salt content, although this had no advantageous effects on the growth of Bromus mollis plants.

**4. Conclusions**

In conclusion, the Jatropha plant cultivated in semiarid and arid regions, such as Egypt, where salt poses a substantial challenge, experiences considerable growth reduction due to salinity stress, as evidenced by both fresh and dry weights. The administration of putrescine, in conjunction with calcium nitrate, significantly alleviates these effects, improving both fresh and dry biomass at different salinity levels. Although putrescine enhances stress tolerance independently, its combination with calcium nitrate seems to provide the most extensive growth advantages, particularly in moderate salinity environments. The findings correspond with contemporary research regarding the function of polyamines and calcium in salinity stress tolerance, indicating that their synergistic use may represent a viable technique for enhancing plant resilience in saline conditions. It is advisable to meticulously oversee and regulate the salinity levels in irrigation water to enhance nutrient absorption and mitigate adverse impacts on plant growth. As nitrogen concentration diminishes with rising salinity, it is crucial to augment nitrogen levels to sustain optimal growth, particularly in high-salinity environments. Moderate salinity may augment potassium (K) and magnesium (Mg) absorption; however, elevated salinity levels typically result in a reduction of their concentration, underscoring the necessity for meticulous nutrient management at such levels. Moreover, phosphorus absorption diminishes as salinity escalates, whereas calcium (Ca) concentration exhibits variable responses contingent upon the salinity level, indicating that nutrient administration changes should be tailored to specific salinity conditions.

To alleviate the detrimental impacts of salt stress on plant growth, the use of calcium and polyamines is recommended. Calcium is essential for improving salt tolerance by preserving cell membrane integrity, regulating osmotic equilibrium, and stabilizing cell walls. The application of exogenous

polyamines can mitigate stress-induced damage and enhance growth in high salinity environments. Calcium can mitigate sodium accumulation in plant tissues, although its effect on overall growth may differ based on plant species and environmental conditions.

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